A statewide experience with endovascular abdominal aortic aneurysm repair: Rapid diffusion with excellent early results

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Objective: **The purpose of this study was to compare survival and outcomes of endovascular versus open repair of abdominal aortic aneurysms (AAAs) in New York State (NYS).**

Methods: **We used the NYS discharge dataset Statewide Planning and Research Cooperative System (SPARCS) to analyze the outcomes of elective admission for nonruptured (International Classification of Diseases–9th revision [ICD-9] 441.4) open aneurysm repair (38.44) and endovascular aneurysm repair (39.71) during the years 2000-2002. The ICD-9 code for endovascular repair was introduced in late 2000, thus capturing 3 months of empiric data for 2000.**

Results: **There has been a significant increase in the number of AAA procedures performed in NYS (comparing before and after 2000: average, 1419 vs 1701; $P = .0001$), temporally coinciding with the implementation of training programs after US Food and Drug Administration approval of endovascular grafts and the new payment code. From 2000 to 2002 the number of NYS hospitals performing endovascular repairs increased from 24 to 60. By 2002 there were more endovascular repairs being performed than open repairs (871 vs 783). The target population for these surgical interventions showed interesting differences. In 2002, women had a 43% chance of receiving an endograft, whereas men had a 55% probability. The use of endovascular repair over the observation period was relatively constant in patients younger than 65 years. In patients older than 65 years, and especially those older than 75 years, endovascular use increased substantially, so that by 2002 older patients were more likely to undergo endovascular repair than open repair. Patients who underwent endovascular repair had significantly more hypertension, coronary artery disease, diabetes, and hyperlipidemia than did patients who underwent open repair. Yet the mean length of stay for endovascular procedures was approximately 3.6 days, and for open procedures was about 10.3 days, across all 3 years ($P = <.0001$). Moreover, patients who underwent endovascular repair had statistically fewer postoperative complications and significantly lower mortality. In-hospital mortality in 2001 was 3.55% for open repair and 1.14% for endovascular repair ($P = .0018$), and in 2002 these rates were 4.21% versus 0.8% ($P < .0001$), respectively.**

Conclusion: **This dataset suggests that endovascular AAA repairs are being performed in a patient poplation with a higher frequency of comorbidities. However, endovascular repairs still are associated with significantly lower in-hospital mortality, fewer postoperative complications, and a dramatically shorter length of stay. These results suggest that, despite the rapid diffusion of this new technique, early perioperative outcomes may be superior to those with conventional open repair. However, prospective clinical studies are needed to confirm these insights, and such studies may require the infrastructure of consortia of hospitals or society-based registries. (J Vasc Surg 2004;39:10-9.)**

Despite advances in technique and perioperative care, open repair of abdominal aortic aneurysms (AAAs) is still associated with significant perioperative risk. Large observational studies as well as multicenter randomized trials have repeatedly demonstrated mortality rates with open repair ranging from 1% to 10%.[1-6] Consequently, many patients at high risk with severe coexisting coronary artery disease or advanced pulmonary disease are not offered repair. In view of the limitations of open repair, a less invasive approach to aneurysm exclusion has been pursued. Four endografts are currently approved by the US Food and Drug Administration (FDA). Although the long-term durability and effectiveness of this technique remains somewhat uncertain, endoluminal repair has been embraced with enthusiasm by both patients and physicians.

It was initially hypothesized that endovascular aneurysm repair would substantially reduce patient discomfort and dysfunction. Small prospective studies have demonstrated an earlier return to baseline function, resulting in reduction in the usual postoperative convalescence time by at least 1 month.[7,8] It was also expected that endovascular repair would decrease morbidity and mortality, particularly in patients considered at high risk for aneurysm repair; this hypothesis, however, has been more difficult to prove. Although several individual institutions have reported ben-

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efit with regard to mortality for endovascular versus open repair,[9,10] other multicenter trials reveal mortality and morbidity rates that are equivalent for these two techniques.[11-13]

Moreover, it has been well-documented in other areas of vascular intervention that experience and volume are critical to achieving excellent outcomes. The technique of endovascular aneurysm repair is demanding, and trials to date have been carefully confined to centers where there is particular interest in this approach. Consequently, concerns have been raised about the transition of endovascular aneurysm repair from trial centers to the community at large. Adding to this concern is that training for two of the most commonly used FDA-approved grafts involved only 2 days of instruction, with little or no hands-on experience.

To gain a better understanding of the outcomes of endovascular repair after release of FDA-approved devices, we examined the New York State (NYS) hospital discharge database (Statewide Planning and Research Cooperative System [SPARCS]) for the years 2000 to 2002. Although grafts for endovascular aneurysm repair were initially FDA-approved in 1999, the Health Care Financing Administration (now Center for Medicare and Medicaid Services) did not introduce an International Classification of Diseases–9th revision [ICD-9] procedure code until October 1, 2000. The new ICD-9 code enables tracking of this procedure through state and national hospital discharge databases. In NYS, we were successful in identifying more than 1700 discharges following endovascular aneurysm repair over 27 months. Consequently, we compared patient characteristics and outcomes of those receiving conventional aneurysm repair with those of patients undergoing endovascular procedures during the same period.

METHODS

Discharge data for patients who underwent elective AAA repair between 1995 and 2002 were extracted from the NYS SPARCS database. Legislatively mandated in the 1970s, this system has been collecting hospital discharge abstracts for more than 25 years (http://www.health.state.ny.us/nysdoh/sparcs/sparcs.htm). The database includes more than 50 million discharges from 1977 to the present, and it covers about 225 hospitals in the state of New York. These data are maintained by the New York Department of Health, and they contain information on every patient discharged from an acute-care, nonfederal hospital. Ninety-five percent of the hospital's SPARCS data must be submitted 60 days following the month of the patient's discharge and 100% of the data is due 180 days following the end of the facility's fiscal year. This dataset has been used to support many informative studies of surgical procedures, including aneurysm repair, cardiovascular interventions, carotid endarterectomy and cerebral aneurysms repair.[14-18] From 1995 to 2000, we analyzed the annual volume of elective AAA repair; for the years 2000 to 2002 we distinguished between open and endovascular repair.

An elective patient population was extracted from the SPARCS dataset by using "admission type 3" as our first filter. This variable designates only "elective admissions." Next we selected patients on the basis of principal diagnoses. Patient discharges with the principal diagnosis code 441.4 (Abdominal aneurysm without mention of rupture) were included, thereby excluding ruptured AAAs and thoracoabdominal aneurysms. The type of surgical repair that patients received was identified by the ICD-9 codes. Patients discharged after open AAA repairs had a principal ICD-9 procedure code of 38.44 (Resection of abdominal aorta with replacement).

The FDA approved both the AneuRx and Ancure grafts on September 28, 1999. The official ICD-9 procedure code for endovascular repairs (39.71) was not introduced until a year later (October 1, 2000), marking the new federal fiscal year. Before this time the coding of endovascular repairs was extremely variable. Prior to the introduction of the new ICD-9 code, endovascular repair was often coded under 38.44 or 39.52 (other repair of aneurysm). The designation code 39.52 includes coagulation, electrocoagulation, filipuncture, methyl methacrylate, suture, wiring, and wrapping, and it was excluded from the analysis, because it contains such a wide range of alternative procedures.

For the per capita calculations, statewide census information was obtained from both the National Census Bureau and NYS. The estimated NYS population for 2002 is 19,157,532, whereas the 2001 census cites the population as 19,084,350. Because specific subgroup estimates are not available for 2002 (eg, gender, race, age), we used 2001 data for 2002 per capita calculations. The characterization of hospitals as teaching hospitals was based on the directory of the Association of Academic Medical Colleges (Washington, DC), and data for hospital bed size was from the American Hospital Association.[19]

Statistical analysis. Proportions were compared with the χ^2 test, means were compared with the Student *t* test, and medians were compared with nonparametric tests. When two factors were analyzed simultaneously, a two-factor analysis of variance was used (PROC GLM, SAS). Procedure frequencies were analyzed using poisson regression methods. Results were expressed as both *P* values and 95% confidence intervals (95% CI). All data were analyzed with SAS system software (SAS Institute, Cary, NC).

RESULTS

Diffusion of AAA repairs in NYS. The trend in elective AAA repairs between 1995 and 2002 is shown in Fig 1. Between 1995 and 2000 the total number of elective AAA repairs performed in NYS remained relatively stable (notrend observed, $P = .3032$). In 2001 the total number of procedures performed in NYS increased significantly. This increase temporally coincided with the implementation of training programs in endovascular repair after FDA approval of the two endografts and the new endovascular payment code (ICD-9 code introduced in late 2000). Comparing the average number of AAA repairs before and after 2000 (1419 vs 1701), we found a significant increase (20%; $P = .0001$). In 2001 40% of all AAA repairs were

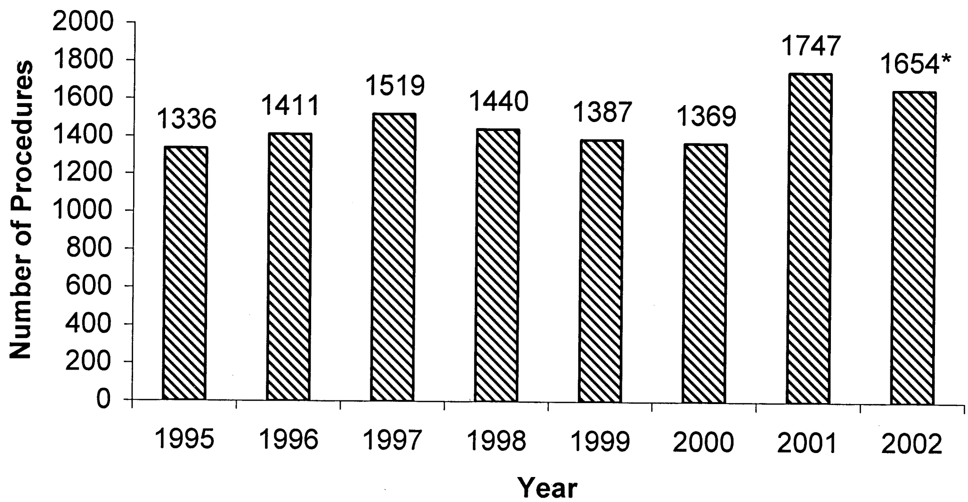

Fig 1. Elective repair of abdominal aortic aneurysm. The 2002 data from the New York State Department of Health Statewide Planning and Research Cooperative System dataset were 95% to 96% complete at the time of analysis. *Cross-hatched bars,* Total number of AAAs.

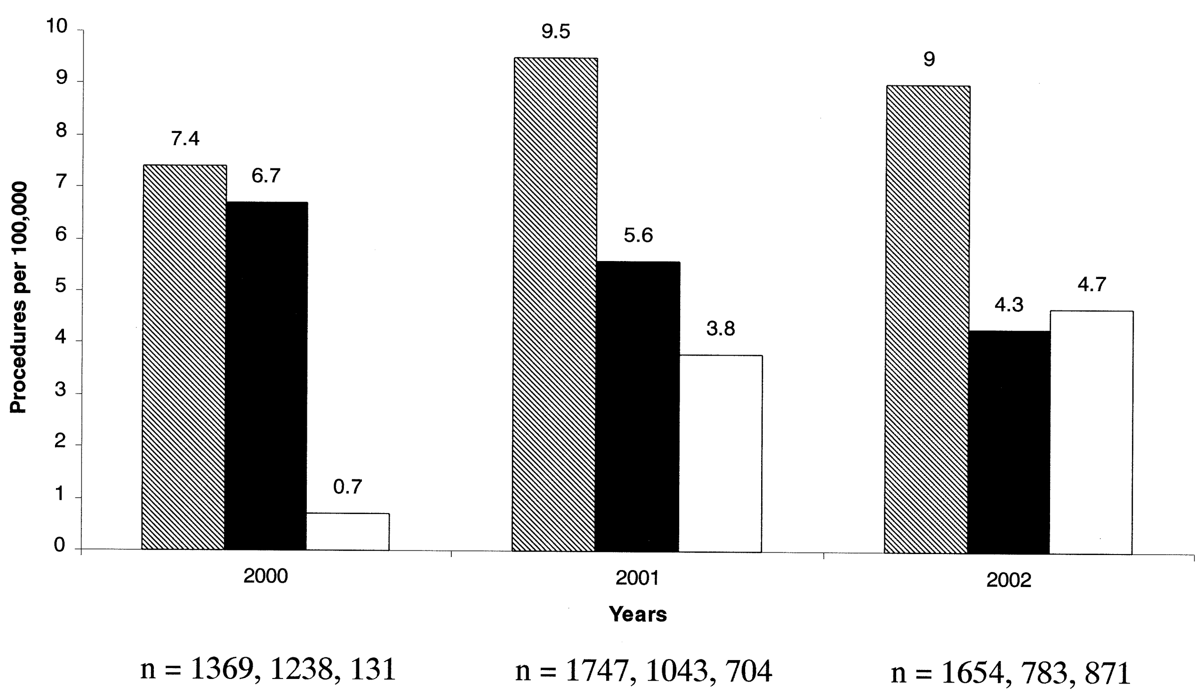

Fig 2. Per capita abdominal aortic aneurysm repairs by year and type. *Cross-hatched bars,* Total repairs; *black bars,* open repairs; *white bars,* endovascular repairs.

done by the endovascular approach. By 2002, however, more endovascular procedures were performed than open procedures (871 vs 783). Per capita rates for AAA repair are shown in Fig 2.

From 2000 to 2001 the number of NYS hospitals (approximately 225*) performing endovascular AAA repairs doubled, from 24 to 48, and this number increased to 60 in 2002. During this time, however, the number of hospitals performing open repairs remained constant: 111 in 2000, 110 in 2001, and 101 in 2002. As the new technique disseminated, the regional distribution changed dramatically, whereas the regional distribution for open repairs remained fairly similar over the study (Fig 3). NYS has 62 counties. The number of counties perform-

*This number is approximate, because the subdivisions of hospitals are sometimes listed separately.

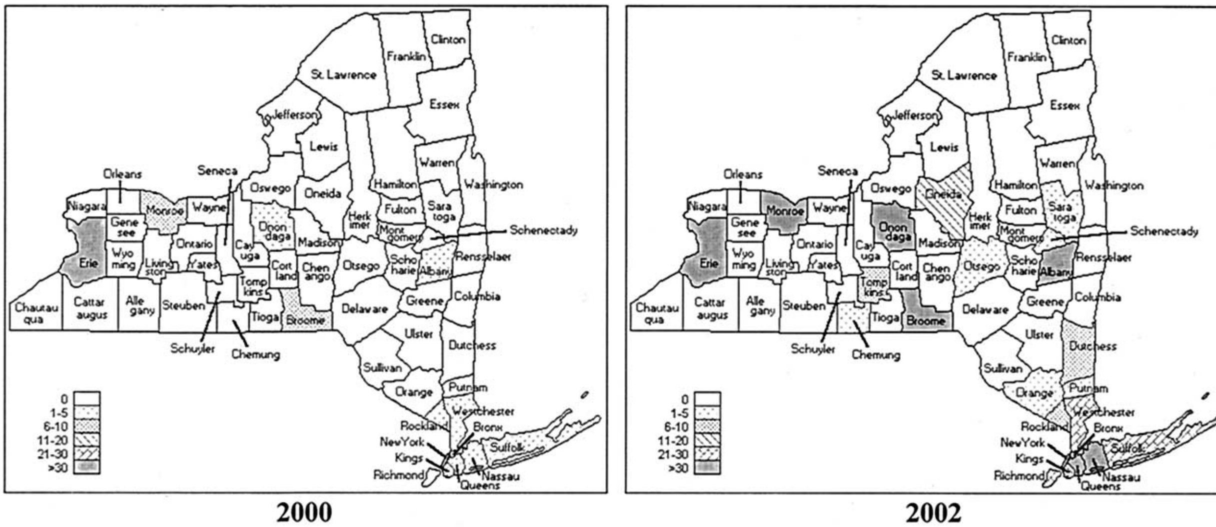

Fig 3. Regional distribution of endovascular repairs.

Table I. Demographic data

	2000		*2001*		*2002*	
	Open (PC)	*Endovascular (PC)*	*Open (PC)*	*Endovascular (PC)*	*Open (PC)*	*Endovascular (PC)*
N	1238 (6.7)	131 (0.7)	1043 (5.6)	704 (3.8)	783 (4.25)	871 (4.73)
Sex						
Male	77% (10.8)	82% (1.2)	76% (9.0)	83% (6.6)	75% (6.6)	83% (8.2)
Female	23% (3.0)	18% (0.3)	24% (2.6)	17% (1.2)	25% (2.1)	17% (1.6)
Age (y)						
15–44	0.5% (0.07)	0% (0.0)	0.3% (0.04)	0% (0.0)	0.4% (0.04)	0% (0.0)
45–64	15% (4.5)	11% (0.4)	15% (3.6)	12% (1.9)	18% (3.3)	12% (2.5)
65–74	44% (43.4)	37% (3.8)	40% (34.1)	40% (23.3)	38% (24.0)	37% (26.1)
>75	40% (47.1)	52% (6.4)	45% (43.6)	48% (31.5)	44% (32.0)	51% (41.4)
Race						
White	86% (8.3)	82% (0.8)	89% (7.3)	80% (4.4)	89% (5.4)	85% (5.8)
Blacks	3% (1.5)	2% (0.1)	3% (1.0)	2% (0.6)	2% (0.7)	3% (1.0)

PC, Per capita: Number of procedures per 100,000 population.

ing endovascular repair increased from 13 to 23 between 2000 and 2002, and all of the initial 13 counties performing this procedure showed increased volume during these years.

Sixty-two percent of hospitals performing endovascular procedures in 2000 were teaching hospitals. As the procedure disseminated to nonacademic centers, this number decreased to 47% by 2002. In 2000 the endovascular operation was highly concentrated; 82% of all endovascular procedures performed in NYS were done in 10 facilities. However, in 2002 the top 10 hospitals performed only 55% of endovascular procedures. At the same time, nearly 50% of hospitals doing endovascular repairs performed five or fewer procedures annually.

Target population. The demographic characteristics of the patients undergoing elective AAA repair are shown in Table I. By far, most endovascular repairs performed during these years were in men (82%-83%), white patients (80%-85%), and patients older than 75 years (48%-52%). However, during the study period, we able to observe population differences in the use of open versus endovascular repair. In 2002, women requiring aneurysm repair had a 43% chance of receiving an endograft. In contrast, men had a 55% probability of receiving endovascular repair. With respect to race, endovascular interventions were used in over 50% of the AAA repairs performed in both whites and blacks in NYS. (Whites received 739 endovascular out of 1434 total repairs, and blacks received 27 endovascular out of 46 total repairs.) As these numbers indicate, very few black patients underwent aneurysm repair, which limits our ability to analyze this subgroup. Last, the use of endovascular repair over the 3 years of observation has been relatively constant in patients younger than 65 years (No trend observed, $P = .2597$). In patients older than 65 years, and especially those older than 75 years, endovascular use increased substantially; thus, by 2002 older patients were

Table II. Comorbid conditions

	Open		Endovascular		Relative risk	95% CI	P
	%	n	%	n			
Comorbidities (ICD-9)							
2000	N = 1237		N = 131				
COPD (496 + 4928)	23.0	284	25.2	33	0.91	0.67–1.24	.5614
Hypertension (4019)	41.6	514	55.0	72	0.76	0.64–0.89	.0031
CAD (41401)	21.1	261	22.1	29	0.95	0.68–1.34	.7787
Diabetes mellitus (25000)	7.0	87	9.9	13	0.71	0.41–1.23	.2257
Lipids (2720)	9.0	111	14.5	19	0.62	0.39–0.97	.0398
PVD (4439)	3.8	47	3.1	4	1.24	0.46–3.40	.6694
Smoking or history of smoking (3051)	4.0	50	5.3	7	0.76	0.35–1.63	.4771
2001	N = 1043		N = 704				
COPD (496 + 4928)	24.4	255	25.6	180	0.98	0.81–1.13	.5956
Hypertension (4019)	45.1	470	54.3	382	0.83	0.75–0.91	.0002
CAD (41401)	18.8	196	24.9	175	0.76	0.63–0.91	.0024
Diabetes mellitus (25000)	7.0	73	10.7	75	0.66	0.48–0.89	.0071
Lipids (2720)	11.9	124	17.9	26	0.66	0.53–0.84	.0004
PVD (4439)	2.5	26	5.3	37	0.47	0.29–0.78	.0024
Smoking or history of smoking (3051)	5.5	58	5.3	37	1.06	0.71–1.58	.7826
2002	N = 783		N = 871				
COPD (496 + 4928)	25.8	202	25.8	225	1.00	0.85–1.18	.9874
Hypertension (4019)	43.2	338	55.2	481	0.77	0.70–0.86	<.0001
CAD (41401)	17.2	135	23.7	209	0.80	0.70–0.92	.0013
Diabetes mellitus (25000)	6.8	53	10.9	95	0.74	0.59–0.92	.0032
Lipids (2720)	12.9	101	19.4	169	0.76	0.64–0.89	.0004
PVD (4439)	2.9	23	3.8	33	0.86	0.63–1.19	.3392
Smoking or history of smoking (3051)	7.2	56	8.5	74	1.09	0.87–1.36	.4750
Associated findings (ICD-9)							
2000							
Atrial fibrillation (42731)	12.1	150	9.2	12	1.32	0.76–2.32	.3192
CHF (4280)	11.5	142	6.9	9	1.67	0.87–3.20	.1100
2001							
Atrial fibrillation (42731)	13.4	140	11.9	84	1.13	0.87–1.45	.3606
CHF (4280)	10.2	106	6.7	47	1.52	1.09–2.12	.0114
2002							
Atrial fibrillation (42731)	13.0	102	10.5	91	1.13	0.98–1.31	.1028
CHF (4280)	9.2	72	7.5	65	1.12	0.95–1.33	.2018

COPD, Chronic obstructive pulmonary disease; *CAD,* coronary artery disease; *PVD,* peripheral vascular disease; *CHF,* congestive heart failure; *CI,* confidence interval.

more likely to undergo endovascular repair than open repair (Table I; Increasing trend, $P < .0001$).

When the most commonly coded preoperative risk factors were analyzed, the degree of comorbid disease was found to be higher in patients undergoing endovascular repairs (Table II). There was a significantly higher rate of hypertension, coronary artery disease, diabetes mellitus, and hyperlipidemia in the endovascular group in 2001 and 2002. Because of the limitations of the dataset, two clinical conditions, atrial fibrillation and congestive heart failure, cannot be characterized as either a comorbid condition or a complication of the procedure.

In-hospital mortality and postoperative complications. In 2000 the dataset contained only 3 months of endovascular codes. The overall in-hospital mortality rate was 4.0% (95% CI, 3.1%, 5.2%). For open repairs the mortality rate was 4.1% (95% CI, 3.1%, 5.1%), whereas for endovascular repairs this rate was 3.05% (95% CI, 0.8%, 7.6%). The difference in mortality between operative techniques was not significant (95% CI, −2.1%, 4.2%; $P = .55$; Fig 4).

In 2001 the in-hospital mortality rate was 2.6% (95% CI, 1.9%, 3.4%). The mortality rate for open repairs was 3.6% (95% CI, 2.5%, 4.8%), compared with a mortality rate of 1.1% (95% CI, 0.5%, 2.2%) for endovascular procedures. The mortality difference (2.5%) between the procedures was significant (95% CI, 1.0%, 3.7%; $P = .0018$). In 2002 the overall in-hospital mortality rate was similar, at 2.4% (95% CI, 1.7%, 3.3%). For open repairs the mortality rate was 4.2% (95% CI, 2.9%, 5.9%), whereas the mortality rate for endovascular procedures was 0.8% (95% CI, 0.3%, 1.7%). The mortality difference (3.4%) between the two procedures was significant (95% CI, 1.9%, 4.9%; $P < .0001$).

The three most commonly coded postoperative complications documented in patients with AAA repair were acute post-hemorrhagic anemia, pulmonary insufficiency, and cardiac complications. In both 2001 and 2002, the rate of these complications was significantly higher in patients who underwent open procedures (Table III).

Length of stay. There was a marked difference in length of stay (LOS) for the two procedures. The mean

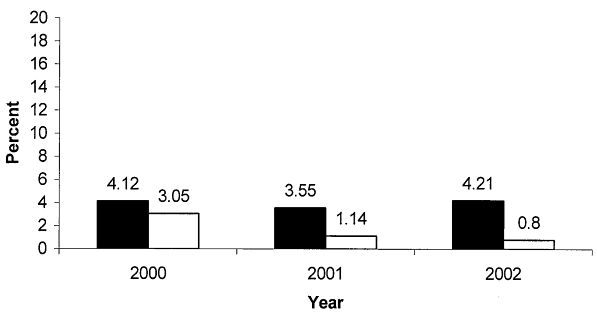

Fig 4. In-hospital mortality after abdominal aortic aneurysm repair. *Black bars,* Open repairs; *white bars,* endovascular repairs.

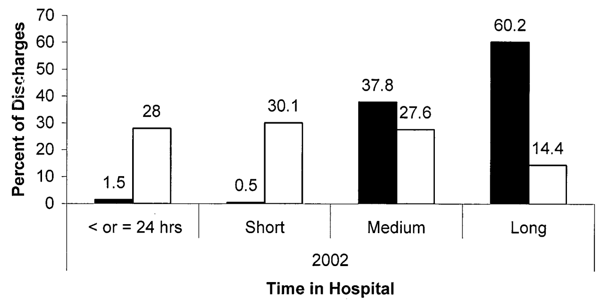

Fig 5. Length of stay, 2002. *Short,* >1 to <3 days; *Medium,* ≥3 to <7 days; *Long,* ≥7 days. *Black bars,* Open repairs; *white bars,* endovascular repairs.

LOS for endovascuar procedures across all 3 years was approximately 3.6 days, and the median was 2 days. By comparison, the mean LOS for open procedures was between 9.9 and 10.6 days for all 3 years, with a median of 7 days. The difference between the procedures was statistically significant ($P = <.0001$).

The LOS data, which include all people operated on regardless of the outcome of their surgery, indicate that nearly 30% of all patients who underwent endovascular repair were discharged in ≤24 hours over the 3-year period, whereas nearly 60% were discharged in less than 3 days. By comparison, on average, 4% of patients who underwent open AAA repair were discharged in less than 3 days for all 3 years combined. Moreover, approximately 60% of all patients who underwent open procedures were hospitalized for 7 days or longer. For simplicity, Fig 5 depicts LOS for both procedures in 2002. All three years had a very similar distribution.

DISCUSSION

During the last 2 years there has been a significant increase in the overall number of AAA repairs performed in NYS, where almost 10% of national hospital inpatient discharges occur. Although a number of factors may contribute to this increase, such as aging of the population, increase in incidental discovery of AAA, growth of diagnostic testing, and heightened public awareness of aneurysms, we believe that the introduction of and reimbursement for endovascular repairs may be a prominent factor. After dissemination of endovascular repair training programs and introduction of the ICD-9 code for endovascular AAA repair, there was a substantial increase in the usage rate per capita for total AAA surgeries. This growth occurred mainly in use of endovascular procedures. By 2002 more endovascular repairs were being performed than open repairs, and the use of this procedure had expanded across hospitals and counties.

This pattern is reminiscent of epidemiologic changes in rates of utilization for gallbladder surgery after introduction of laparoscopic cholecystectomy. The introduction of laparoscopic gallbladder surgery resulted in an increase in the overall rate of gallbladder procedures both by changing the indications for intervention and by expanding the patient pool.[20] Similarly, our data demonstrate the expanded use of endovascular grafts in the elderly. Moreover, recipients of endovascular repair had a greater number of comobid conditions, with higher rates of hypertension, coronary artery disease, diabetes mellitus, and hyperlipidemia, compared with recipients of open repair. These data suggest that use of endovascular procedures has expanded among older and sicker patients. Within the age group 75 years and older, we noted a 31% per capita increase in use of endovascular procedures from 2001 to 2002, with a nearly 27% per capita decrease in open repairs. Although the highest per capita rate of endovascular repair is in patients older than 75 years, it is interesting to note that minimally invasive techniques have not been restricted to the elderly and the infirm, as may have been anticipated.

In 2002 female patients were still more likely to undergo open aneurysm repair; only 43% of interventions were performed with endovascular grafts. This is compared with a utilization rate of 55% in males during the same period. It is widely accepted that endovascular aneurysm repair is more technically challenging in women, because of the smaller size of the iliac vessels and challenging neck anatomy. Despite this, the observed rate of use in women was higher than many would have anticipated. Newer generation devices that are lower in profile will likely increase the use of endovascular repair in female patients.

Although risk adjustment in administrative datasets is difficult, our analysis indicates that patients who underwent endovascular repair had more preoperative comorbid conditions. Despite the higher severity of illness in patients undergoing endovascular repair, in-hospital mortality for this type of repair and postoperative complications were significantly lower than for open repair in NYS. The endovascular in-hospital mortality rate was about 1%. Because our dataset reports only in-hospital mortality rates, rather than 30-day mortality rate, comparison with the literature is difficult. The mortality rate for endovascular repair reported in single and multicenter clinical trials ranges from 0.6% to 9%.[1,21] The reason for this tremendous variability may be related to noncomparability of patients, ie, a different degree of risk or difficulty of the repair. A substantial number of investigators have reported rates for mortality

Table III. Postoperative complications

COMPLICATION (ICD-9)	*Open* %	*Open* n	*Endovascular* %	*Endovascular* n	*Relative risk*	*95% CI*	P
2000	N = 1237		N = 131				
Hemorrhage (2851)	11.4	141	3.8	5	2.98	1.25–7.15	.0076
Pulmonary (5185)	6.8	84	0.8	1	8.89	1.25–63.31	.0066
Cardiac (9971)	6.9	85	3.1	4	2.25	0.84–6.03	.0924
2001	N = 1043		N = 704				
Hemorrhage (2851)	8.1	85	3.0	21	2.73	1.71–4.36	<.0001
Pulmonary (5185)	7.5	78	1.6	11	4.78	2.56–8.93	<.0001
Cardiac (9971)	8.1	84	2.7	19	2.98	1.83–4.86	<.0001
2002	N = 783		N = 871				
Hemorrhage (2851)	12.3	96	3.2	28	1.72	1.54–1.92	<.0001
Pulmonary (5185)	9.3	73	1.4	12	1.90	1.71–2.10	<.0001
Cardiac (9971)	7.8	61	3.3	29	1.47	1.26–1.71	<.0001

CI, Confidence interval.

and morbidity that are equivalent to those for open repair.[11-13] Our data, however, suggest that endovascular aneurysm repair can be broadly applied, with excellent early outcomes. These encouraging outcomes were achieved despite use of endovascular repair in a sicker patient cohort and its expanded use in nonacademic centers.

Despite the higher prevalence of comorbid conditions and elderly patients among those undergoing endovascular repair, LOS was significantly lower for these patients compared with patients undergoing open procedures. There was a marked difference in LOS between these two procedures. On average, approximately 60% of patients who underwent endovascular repair were discharged in less than 72 hours, whereas the same percentage of patients who underwent open repair were hospitalized for 7 days or longer. LOS is an important component of hospital costs, and these data suggest a potential economic benefit from endovascular repair. However, the net cost of endovascular aneurysm repair also depends on the cost of the graft itself, which has remained high; the need for lifelong surveillance; and the potential need for repeat intervention. Several studies have indicated that the potential savings in hospital time may not outweigh these other costs.[22-26] These variables could not be considered in our dataset.

Use of hospital discharge abstracts from secondary sources, such as SPARCS, for epidemiologic research has limitations. First, although these data contain associated diagnoses, they do not contain sufficient information to substantiate these diagnoses, nor do they provide sufficient physiologic data (eg, blood pressure or left ventricular ejection fraction) to accurately characterize the severity of associated illnesses. Moreover, this dataset contains no information on the size and characteristics of the aneurysm itself. Second, these data typically do not identify the time of onset of associated diseases, which sometimes makes it difficult to differentiate between preexisting conditions and postoperative complications. There may also be substantial variation in reporting precision. A body of evidence concerning the accuracy of administrative datasets highlights the high rate of specificity and relatively low rate of sensitivity for some comorbid illnesses.[27,28] Smoking and obesity, both of which have ICD-9 codes, typically have high false negative rates of pickup in databases such as SPARCS. From 2000 through 2002, a mere 4% to 8% of patients with AAAs were recorded as having a history of smoking in the SPARCS dataset. This is in sharp contrast to the rate of smoking among the aneurysm population identified in comparative studies, which is as high as 78% to 85%.[12,29] Finally, we did not have access to patient or surgeon identifiers; thus we were unable to calculate risk-adjusted mortality or conduct volume-outcome analyses. An additional limitation of this type of dataset for comparison between endovascular and open repair is that the common complications associated with open repair (eg, pulmonary, cardiac) are frequently coded, whereas complications that typically are associated with endovascular repair (eg, elevated serum creatinine level, dialysis, graft occlusion) are not. At the same time, several studies have argued that hospital discharge datasets are accurate in determining primary diagnoses, especially of surgical procedures like aneurysm repairs, because professional coders have an incentive to capture all high-reimbursement procedures.[30] In addition, these datasets do not suffer from the selection bias imposed by patient or provider refusal to participate in a study.[31] However, risk-adjustment, necessary in making comparisons in non-randomized studies, is not adequately supported by these datasets. Thus, studies based on these datasets are generally considered hypothesis generating rather than confirmatory.

The diffusion of endovascular repair in NYS raises some interesting questions. For open aneurysm repair, previous research has established that mortality is diminished at "high volume" centers, where more than 30 procedures are performed annually.[32,33] It would be of interest to determine whether a similar threshold is present for endovascular aneurysm repair. In 2002, 60 hospitals in NYS performed endovascular repairs. Twenty percent performed more than 30 endovascular aneurysm repairs per year, while in nearly 50% of the institutions fewer than 5 endovascular procedures were performed per year. In this latter group of hospitals, the crude mortality rate was more than double (1.9% vs 0.8%) that in higher volume hospitals; however, this difference (1.1%) was not statistically significant. Furthermore, this analysis does not adequately correct for differences in risk factors among patients at the different institutions, nor does it capture readmissions and repeat operations. Volume-outcome studies in other fields suggest that large-volume centers often treat sicker patient populations. Finally, because of the small volume of procedures performed annually in some institutions, such analysis must include several years of experience at each institution and also explore the existence of a learning curve phenomenon.

Our analysis demonstrates that endovascular appears to be rapidly replacing open aneurysm repair, which is in striking contrast to the lower rate of usage many predicted when these devices were first released. There was initially a general consensus that endovascular repair should be confined to the elderly and infirm. However, 3 years after the introduction of this technique, more than half of patients receiving aneurysm repair in NYS were treated endovascularly. Although endovascular repair is being offered to older and sicker patients, this technique is also widely used in younger patients who are excellent candidates for open surgical repair. With the introduction of new generation grafts with expanded applicability, the prevalence of endovascular repair will most certainly increase. Recently the results of two large trials have led to the recommendation that AAA repair be reserved for patients whose aneurysms exceed a diameter of 5.5 cm.[34,35] The mortality rates observed in these trials were 3.0% and 5.5%. Decisions regarding the indications for intervention are often predicated on a comparison of risk versus benefit. If future studies, using longitudinal datasets, demonstrate that endovascular aneurysm repair can be performed routinely with a mortality rate of 1%, reevaluation of the threshold for aneurysm repair may be appropriate. Decreased mortality associated with the repair of AAAs will also further enhance the already compelling data that support AAA screening.

Our findings are early and are based on 2 years of diffusion of endovascular repairs. They will require broader experience to substantiate a trend. It should also be emphasized that our data do not address the longer-term issues of surveillance and repeat intervention, which are so critically important in these patients. Nor do our data provide a direct comparison of center outcomes because of limitations in supporting risk-adjusted measurements. Our findings are interesting, however, and suggest that endovascular techniques are diffusing rapidly with excellent early outcomes. Confirmation of these trends requires prospective collection of clinical data, with detailed information on patient characteristics. Large-scale or regional studies of this sort would require the establishment of consortia of hospitals to collect clinical data or society-based registries. In this new era of treatment of aneurysm repair, the use of statewide discharge datasets, confirmed by detailed clinical studies, offers surgeons and policy makers the much-needed information to continuously improve the quality of care for patients with vascular disease.

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DISCUSSION

Dr Jon S. Matsumura (Chicago, Ill). I enjoyed the study. I think it's very important, because you've shown a reduction in mortality with the endovascular compared with open repair in a pretty large dataset.

In studies that I am familiar with, more than two thirds of the early deaths after endovascular repair occur after the patient goes home, so they are no longer inpatients. Because the deaths happen within 30 days, they are counted as surgical.

Can you adjust the mortality rate in your endovascular group to account for the shorter length of stay? Can you compare it with a similar time period for the open? Do you have a 30-day mortality rate for the endo and open groups?

Dr Patrice L. Anderson. We are unable to estimate a 30-day mortality rate; we can only estimate in-hospital mortality. Our access to the New York State dataset (SPARCS) did not include patient identifiers; consequently we were unable to follow rehospitalizations or evidence of deaths out of the hospital. It is important to reemphasize that we have only analyzed in-hospital mortality rates for this presentation.

Dr Satish C. Muluk (Pittsburgh, Pa). I have two questions for you. Do you think the differences between endovascular and open mortality results could be related to the difference in the type of aneurysms being done among the open patients in this time period? And second, the increase in numbers that you saw over the time period, could that have any connection with patients being sent in from out of state to the big centers in New York that would be doing endovascular repair during this period?

Dr. Anderson. I fully agree with your first statement. It may be that the patients who are getting open repair have technically difficult anatomy and that they were not candidates for endovascular repair because of the complexity of their case. The type of aneurysm and the technical difficulty are clinical details that are not available in large administrative datasets such as SPARCS.

I also agree with the second statement. Patients may have migrated into New York State to the centers capable of doing endovascular repair. What we found is that centers performing endovascular repairs did approximately 60% of the open cases in 2000, but by 2002 they were doing about 78% of the open repairs. This may indicate that there is some concentration of open repairs in the institutions that are capable of endovascular intervention.

Dr Richard M. Green (Rochester, NY). That was nicely presented, and I appreciate your sending me the manuscript.

I think these results are of critical importance, because they show that with the introduction of the new technology, and no basis of past experience, community-based surgeons can already get better results than with conventional therapy. And I think you're to be congratulated for bringing this to our attention.

Many of us have criticized the 1-day, 2-day training programs, but clearly they work. Can you tell us more about the learning curve though? I'd be very interested to know, on day 1 are the results as good as at year 5 of experience?

Dr Anderson. From our current data I am unable to conduct a longitudinal analysis of how many cases an institution has done in total, but that would be very interesting for us to look at in the future.

I can say that the smaller volume centers, performing one to five cases per year in 2002, have a comparable mortality rate to the teaching institutions and the centers doing a large number of cases.

The relationship of volume to outcome is always a very interesting and intriguing concept. A challenge with this dataset is that we do not have patient identifiers, which would be needed to adequately adjust for preexisting medical conditions. Consequently, we do not have the basis to say that the mortality at the community level is the same, better, or worse than the rate in a teaching institution, because there may be sicker patients going to the teaching institutions, or vice versa. Though we did look at the